Design of a Cogeneration Hybrid Propulsion System for Commuter Aircrafts With Thermal Recovery

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YES WE ACHEON!

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The present work has been performed as part of ACHEON Project | ACHEON Project - Aerial Coanda High Efficiency Orienting-jet Nozzle project, with ref. 309041 supported by European Union through the 7th Framework Programme (www.acheon.eu).

We have a dream…

acheon

UNIVERSITY OF LINCOLN

nimbus

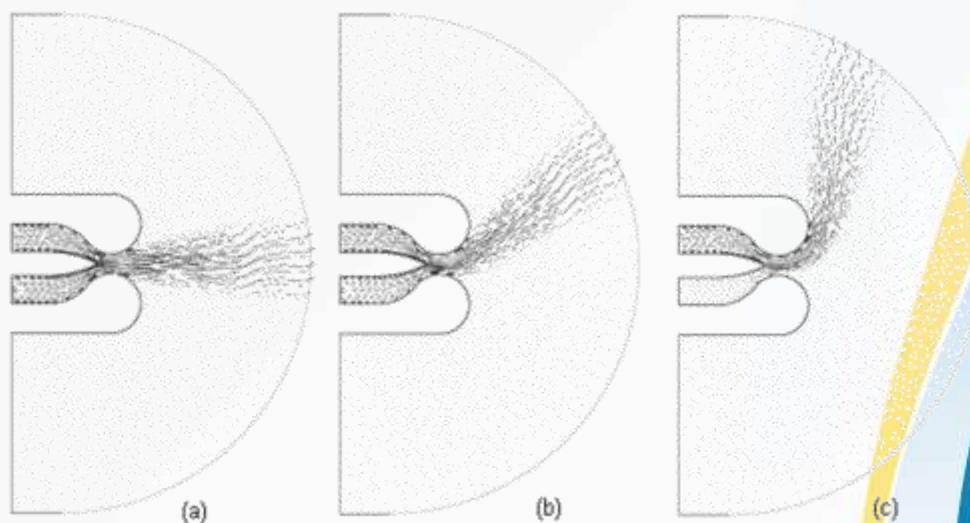
Vrije Universiteit Brussel

REi

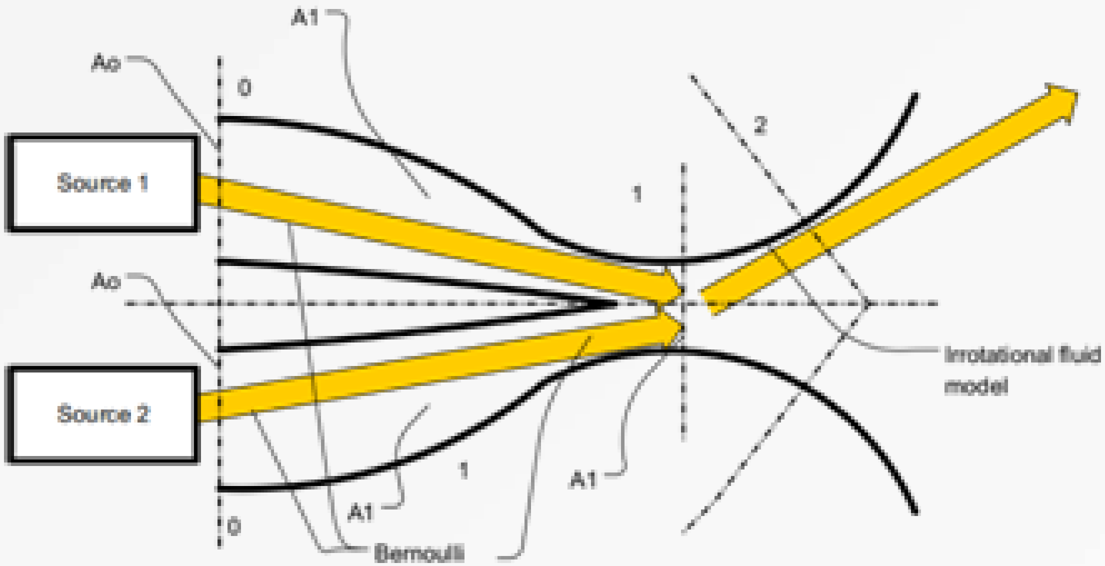
Control of dynamic deflection of a jet without any part in movement:

- **Fluiddynamic**
- **Electrostatic**

- **Propulsion;**
- **Distribution of chemicals**
- **Acclimatizing**
- **Deicing**
- **Technological Applications**
- **Etc.**



Coanda effect: something exoteric…



Bradshaw

$$\theta = f \cdot \sqrt{a \cdot b \cdot \frac{P_{wall} - P_{\infty}}{\rho \cdot u^2}}$$

Newman

$$u_p = \frac{P_s - P_a}{P_0 - P_a} = -\left[2\frac{b}{a} + \left(\frac{b}{a}\right)^2\right]$$

So and Mellor

$$u / u_{pw} = \left[(P_t - P_r)/(P_r - Psw) + e^{-2ky}\right]^{1/2}$$

$u_{pw}=[2Pr\text{-}P_{sw}]^{0,5}$

$\delta P/\delta y = k\,\rho\,u^2$

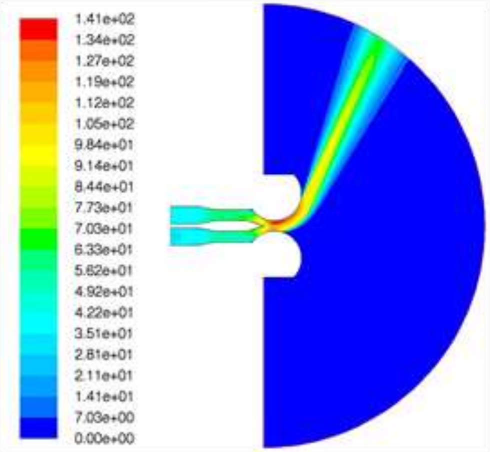
Von Karman

$$\mu \frac{d^2u}{dy^2} = \frac{dp}{dx}$$

Yes we ACHEON!

45.7-35.3 m/s

40-35 m/s

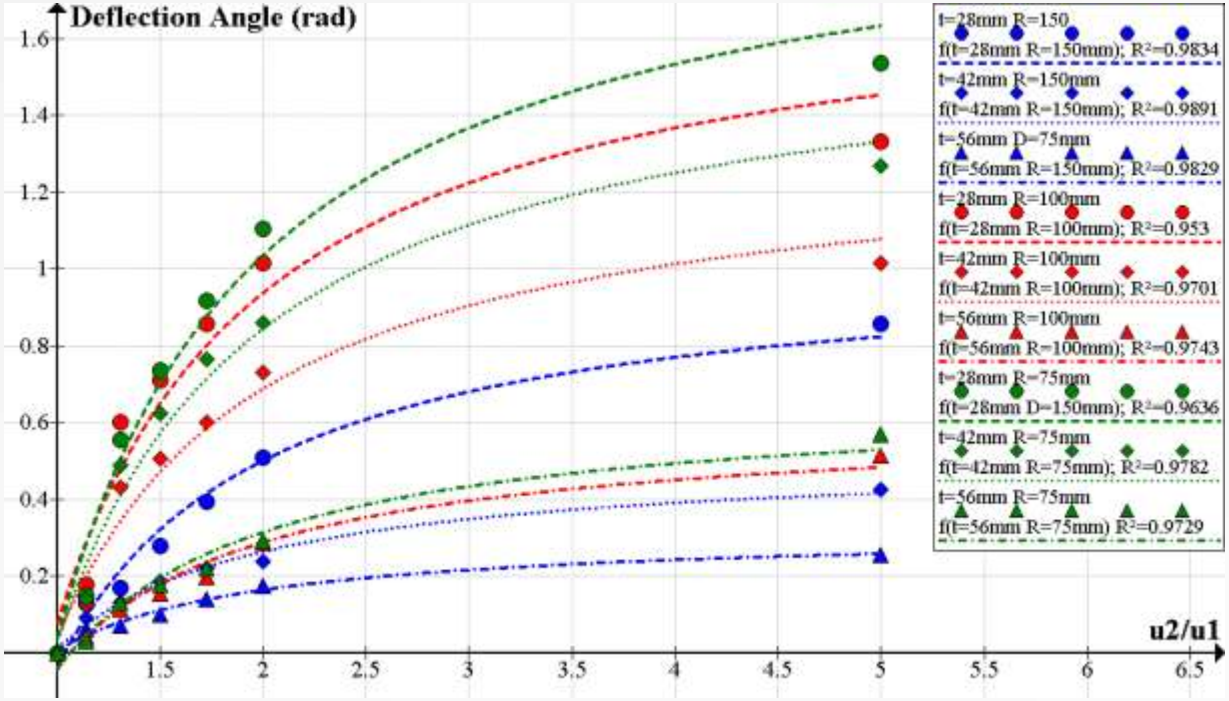


- The fluid stream is subject to a difference of pressure that equilibrates the centrifugal force.
- frictional effects that are depending on the velocity u

$$\frac{\partial P_r}{\partial r} = \rho \cdot \omega^2 \cdot r = \rho \cdot \frac{u^2}{r} \qquad \tau = \mu \cdot \frac{\partial u}{\partial r} = c_f \cdot \frac{\rho \cdot u^2}{2}$$

$$u(r) - u_{\min} = \frac{R}{r} \cdot \Delta u_1 \rightarrow u(r) = \frac{R}{r} \cdot \Delta u_1 + u_{\min,1}$$

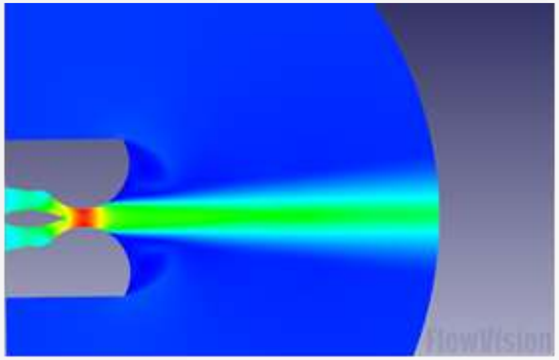
100% indipendent validation

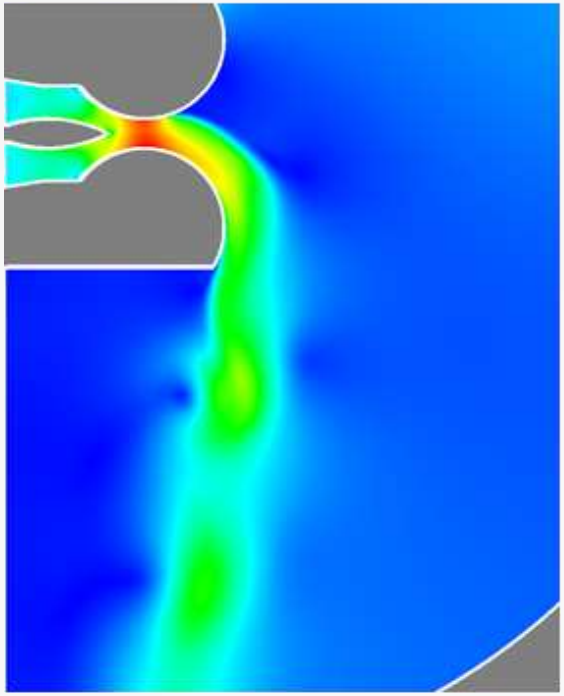


very preliminary model presented by Unimore, from which the project starts, is acceptable
Drăgan V.: A New Mathematical Model for Coandă Effect Velocity Approximation. INCAS Bulletin, vol.4, pp.85–92, 2012.

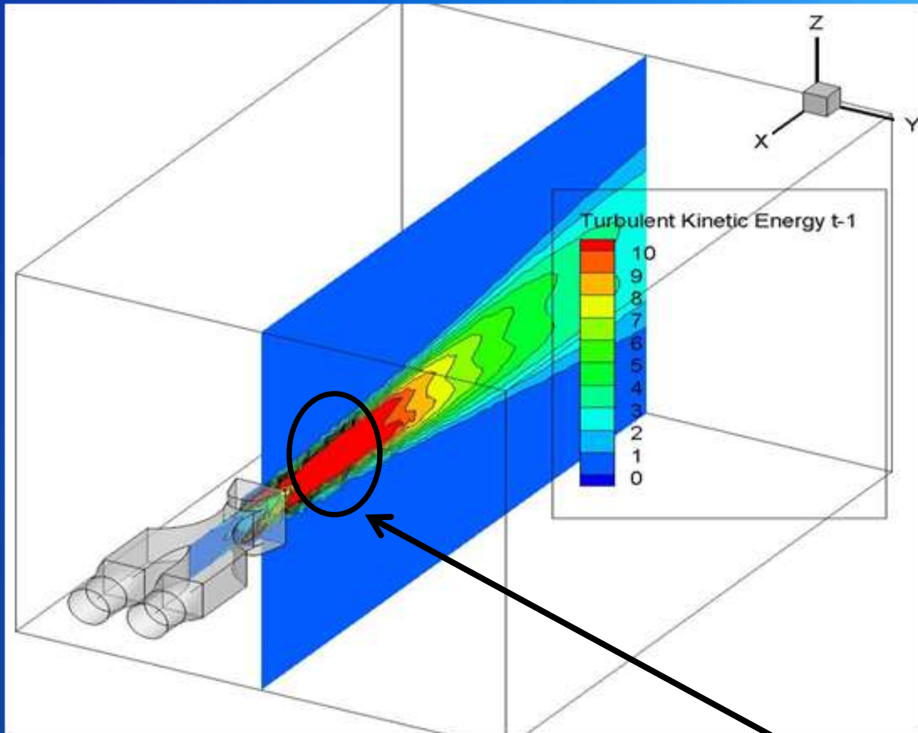
the last presented models works properly even if it needs to be implemented regarding better turbulence models and swirl.
Dragan V., "Reynolds number calculation and applications for curved wall jets", INCAS Bulletin, Volume 6, Issue 3, pp. 35 – 41, (2014).

Computations

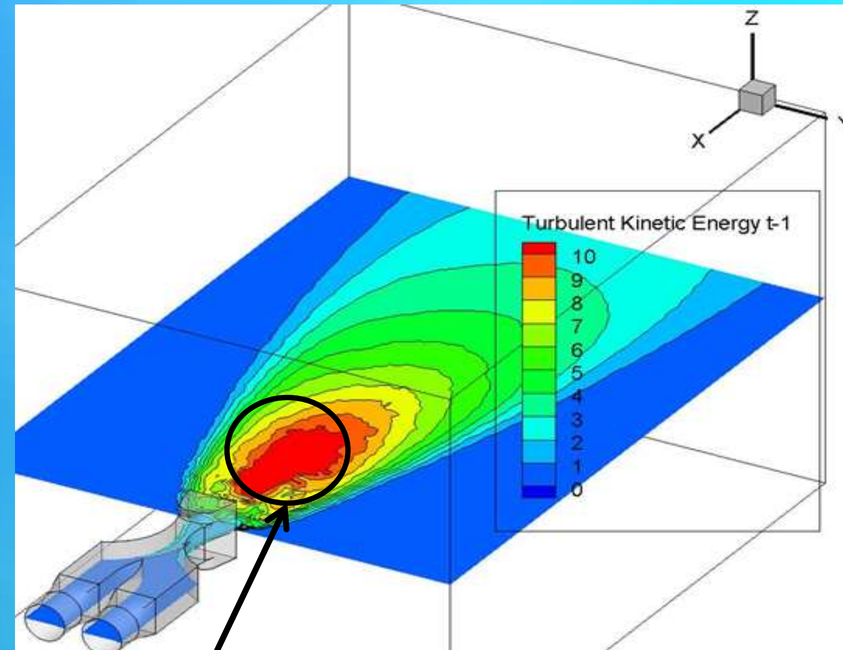




Mass velocity [kg/m2s]	60-60	58-62
Fx [N]	42.15	12.35
Fy [N]	0	41.92
Thrust angle [o]	0	73.35
Efficiency [-]	0.73	0.72



Turbulent Kinetic energy (k) at y = 0



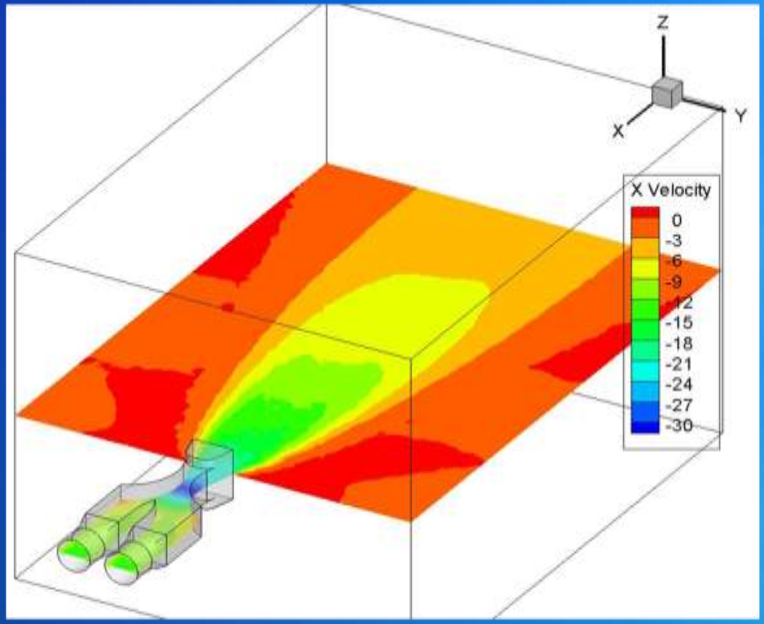
Turbulent Kinetic energy (k) at z = 0

Control zone of interest

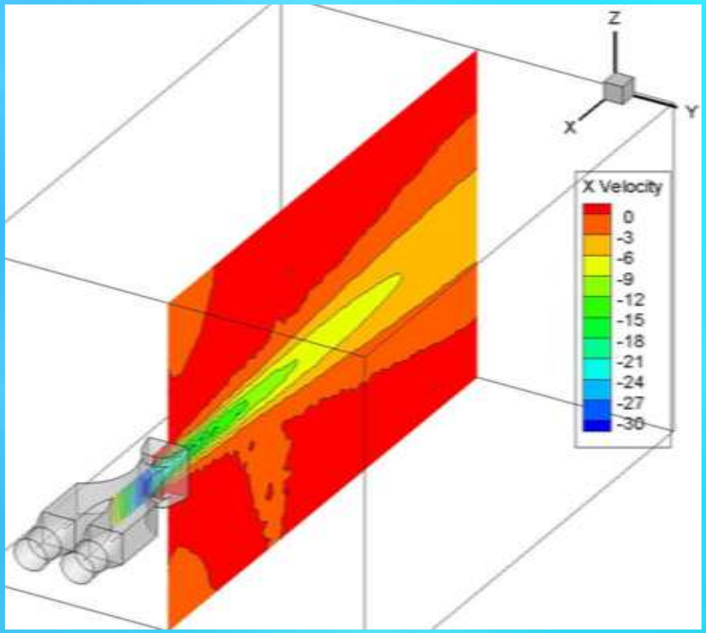
The turbulent kinetic energy shows that the control zone of jet is not just after the exit flow. What was the intuition before computation.

It is located little bit away from the exit.

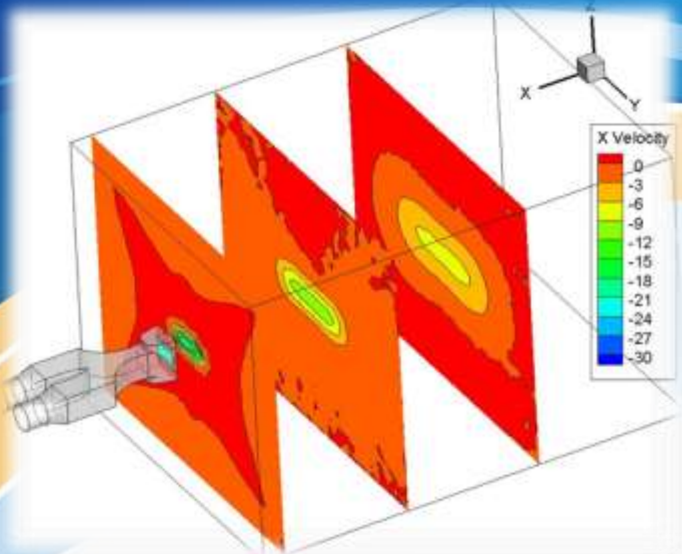
High turbulence zone in z plane indicates the fact.



Flow field for x-velocity for z = constant for 3D simulation of the nozzle



Flow field for x-velocity for y = 0 for 3D simulation of the nozzle

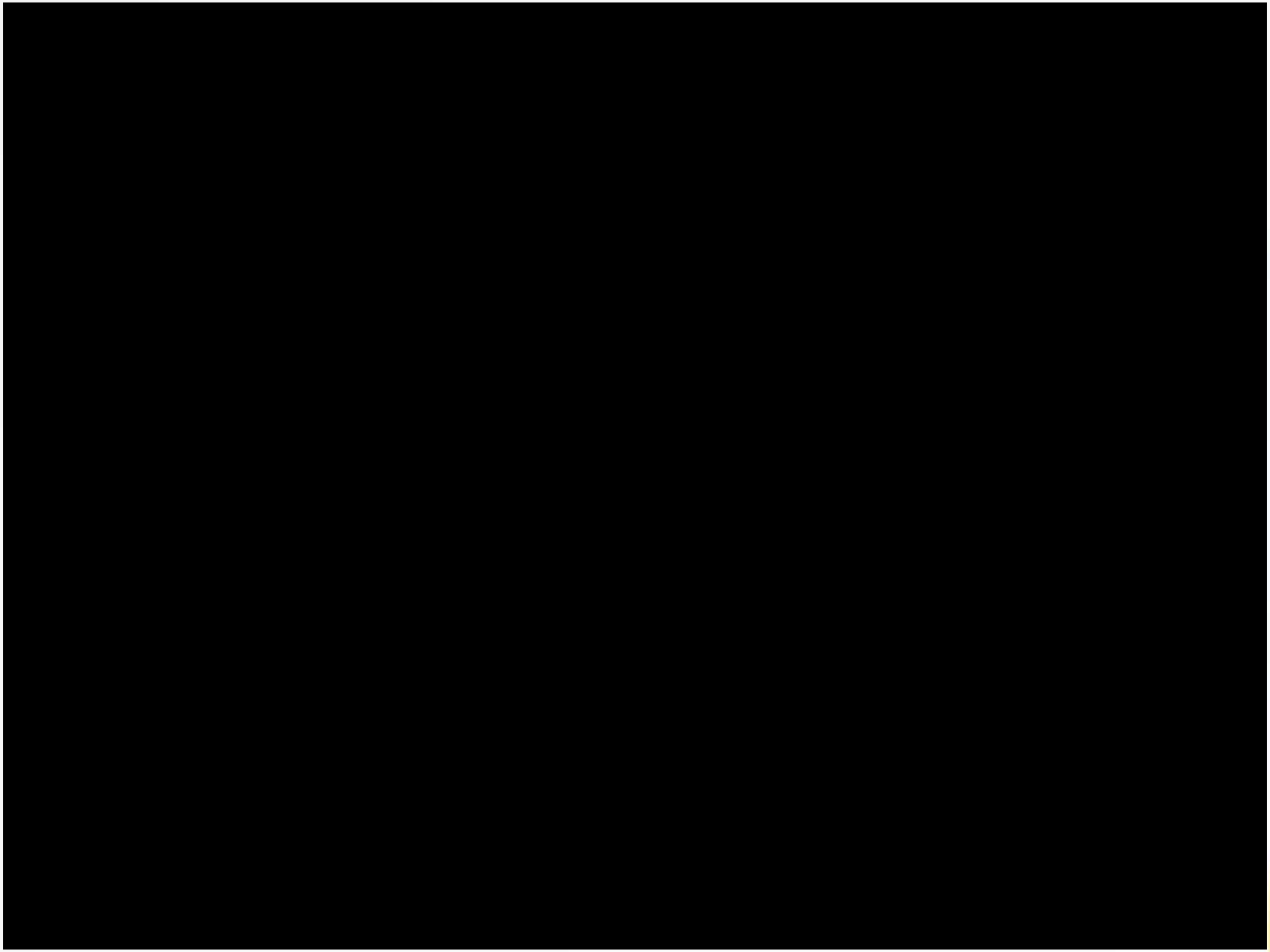


Flow field for x-velocity in x - direction

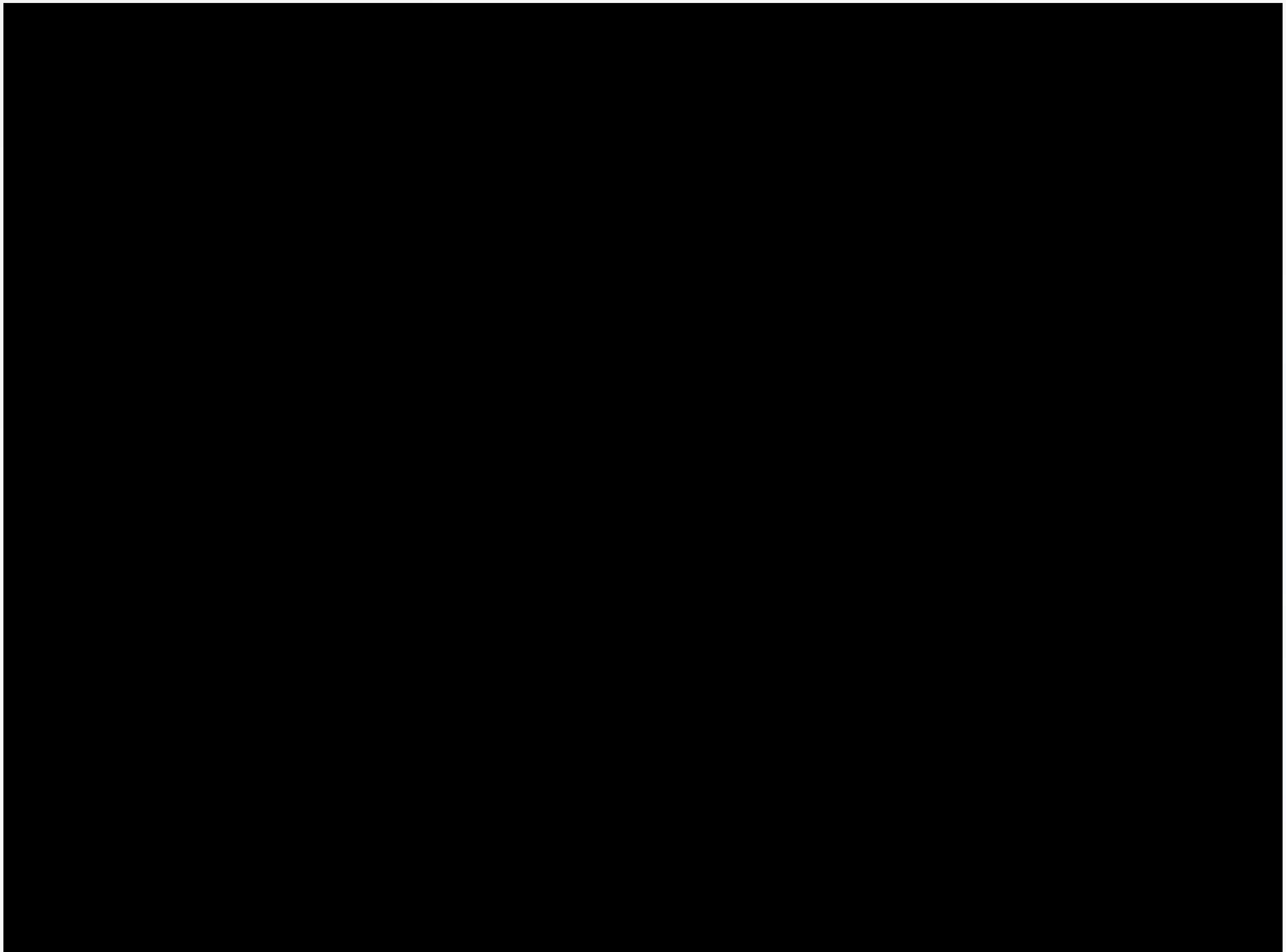
For the inlet velocity 10m/s, at the throat 30 m/s velocity is obtained.

Even slight velocity ratio for 1.5 (15ms-1/10ms) is able to deviate the jet either side.

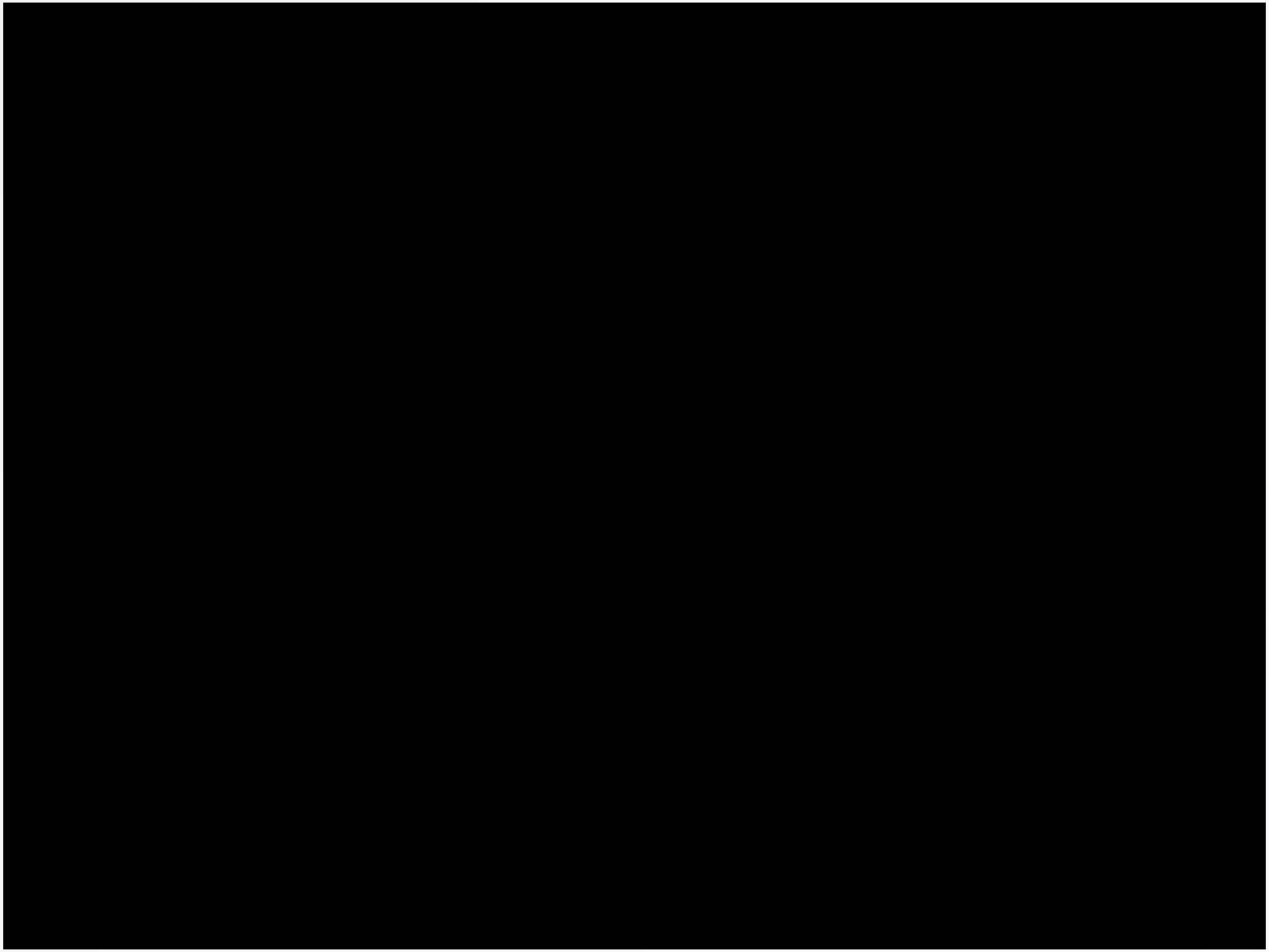
And some experiments…



And some experiments…



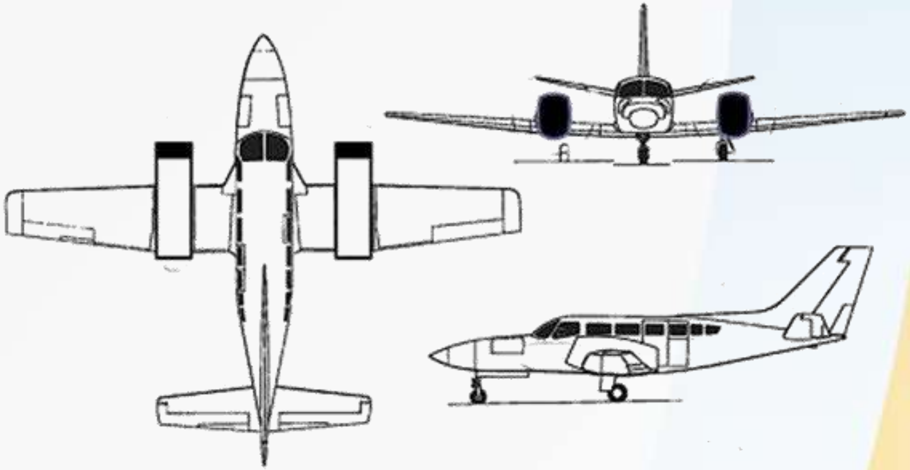
And some experiments…

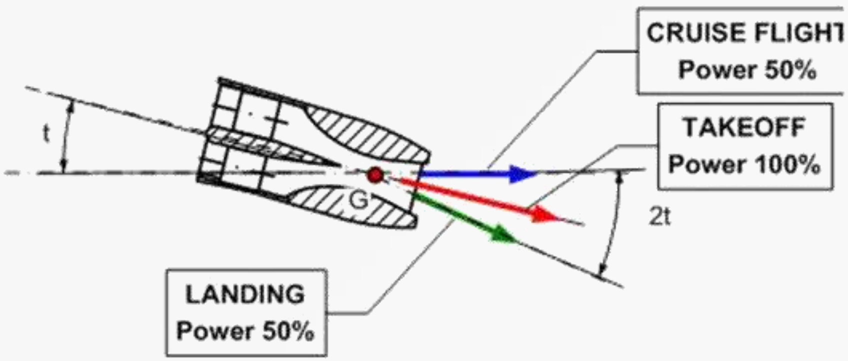


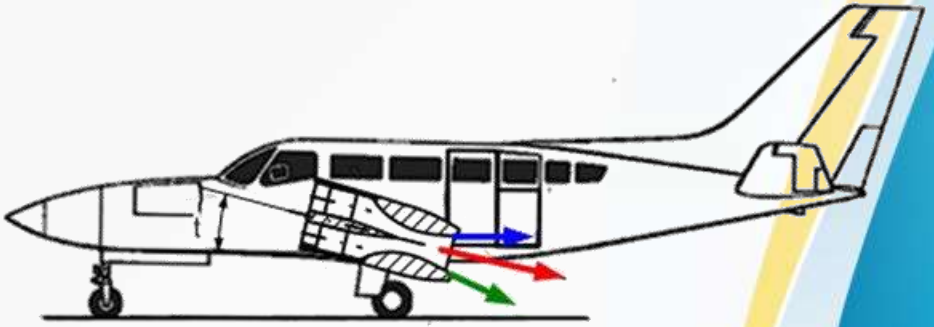
Can it work on airplanes?

- A wonderful work has produced by UoL
- Cen Z., Smith T., Stewart P., and Stewart J, "Integrated flight/thrust vectoring control for jet-powered unmanned aerial vehicles with ACHEON propulsion", Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, first published on July 29, 2014
- It demonstrates that the nozzle increases the maneuvrability of an aiplane with surprising results.

Acheonizing an old fashioned plane…







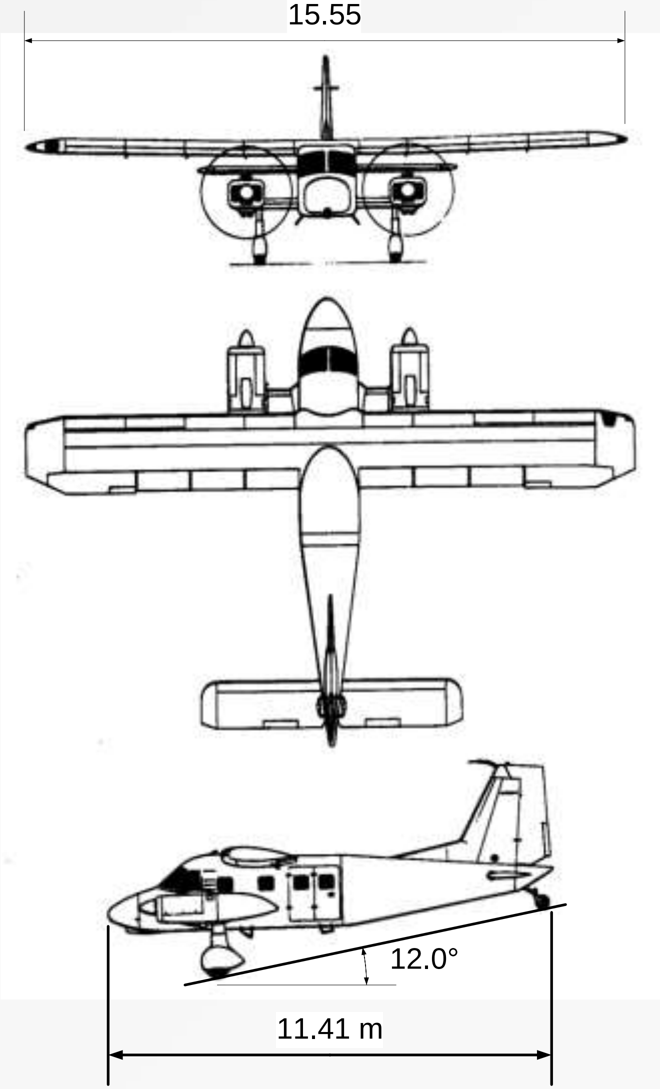
And now some boring numbers!

Empty weight	*Lb*	*4,069*
Useful load	*Kg*	*662*
Max takeoff weight	*Kg*	*3107*
Max on board fuel	***Batteries (Boston Power Swing® 5300 Rechargeable Lithium-ion Cell)***	
	Kg	*1050*
	Wh/kg	*207*
	Ah	*4,420*
	Fuel	
	Kg	*640*
Propulsion		
Cogen	*Rolls Royce Model 250*	
Power	*kW*	*250*
Mass	*Kg*	*250*
Motor	*Four Plettemberg Nova 150 mounted in two ACHEON Nozzle*	
Power	*kW*	*150*
Mass	*Kg*	*11.5*
Performances		
Max speed	*m/s*	*118.9*
Max cruising speed	*m/s*	*109.4*
Stall Speed	*m/s*	*46.3*
Stall Speed Carriage	*m/s*	*25.1*
Initial rate of climb	*m/s*	*7.366*
Service ceiling	*M*	*8200*
Long range cruising speed	*m/s*	*84.4*
Range with reserves at economical cruising speed	*km*	*2000*

	Propellers	*ACHEON*							
Angle of deflection		*15°*		*10°*		*5°*		*0°*	
Direction of		*Tx*	*Ty*	*Tx*	*Ty*	*Tx*	*Ty*	*Tx*	*Kg*
Thrust	*5185.2*	*5009*	*1342*	*5106*	*900.4*	*5166*	*451.9*	*5185*	*kW*
Max Power	*280*			*280*					*m/s*
u_{stall}	*46.3*		*26.3*		*32.9*		*39.5*	*46.3*	*m/s*
$u_{stall,carriage,\ down}$	31.74		*18*		*22.6*		*27.1*	*31.7*	*Kg*
Take off mass	*3105*			*3105*					*m/s*
Lift Off Speed	*50.93*		*28.93*		*36.19*		*43.45*	*50.93*	*m/s*
Take off Speed	*55.56*		*31.56*		*39.48*		*47.4*	*55.56*	*m*
Liftoff Length	*641.5*		*206.8*		*323.4*		*468.4*	*690*	*m*
Takeoff Length (calculated)	*690*		*222.4*		*347.8*		*503.8*	*690*	*m*
Take off length declared	*670*								*m/s*
Lift Off Time	*16.5*		*9.48*		*11.9*		*14.32*	*16.5*	*S*
Take Off Time	*17.74*		*10.2*		*12.8*		*15.4*	*17.74*	*kJ*
Energy needs	132012		27468		31068		34668	44280	*kJ*
Energy saving	0		104544		100944		97344	87732	-
Energy saving	0		79.19%		76.47%		73.74%	66.46%	

	Configuration					
	Cessna 402	**Cessna 402 ACEON**				
Flight Condition:	**traditional**	**15°**	**10°**	**5°**	**0°**	
Take-Off	*132012*	*27468*	*31068*	*34668*	*44280*	kJ
Second Take-Off Segment	*504000*				*139100*	kJ
Enroute (30min)	*1908000*				*636000*	kJ
Approach Segment	*267120*				*53000*	kJ
Landing Segment	*396036*	*8240*	*9320*	*10400*	*13284*	kJ
Energy consumption	*3207168*	*863808*	*868488*	*873168*	*885664*	kJ
Max on board energy	*0*				*1229580*	kJ
Reserve	*-3207168*	*365772*	*361092*	*356412*	*343916*	kJ

And now… the best commuter ever built…



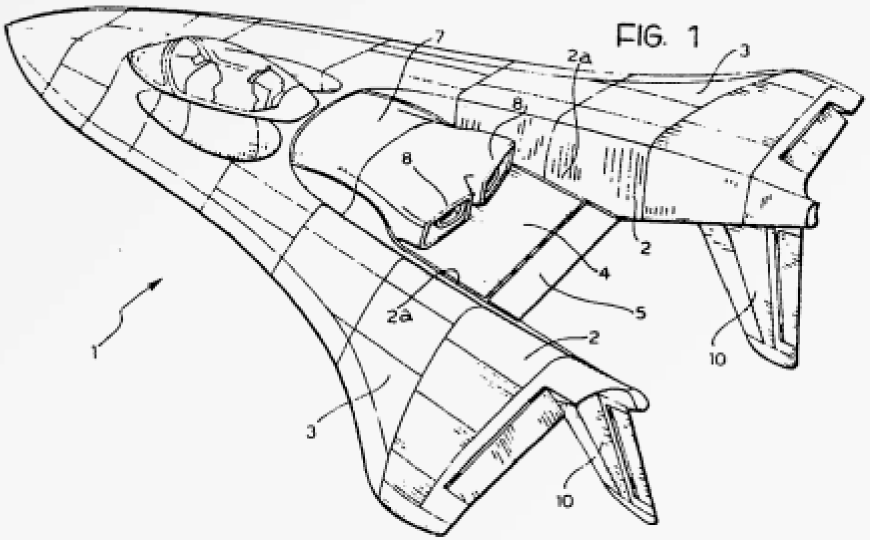
Power	150	kW
Fan Diameter	1100	mm
Hub Diameter	120	mm
Max Fan Speed	6000	RPM
FOM	0.9	
Blade Angle Delta	0.36	Rad
	20.75	Deg
Fan Swept Area	0.94	m^2
Fan Blade Tip Speed	348.10	m/s
Fan Blade Tip Mach	1.02	m
Disk Power Loading	159.74	kW/m^2

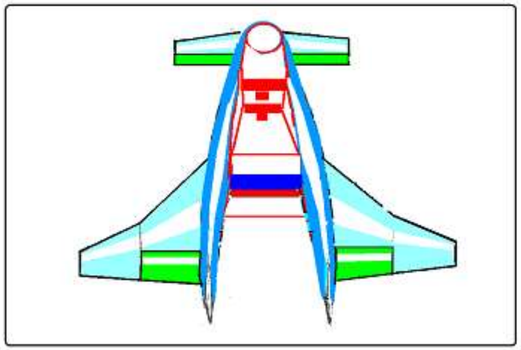
n2/n1	Ttot		Angle	Teff	Tx	Ty
(-)	(kg)	(N)	(deg)	(N)	(N)	(N)
1	708.31	6948.54	0.00	6601.11	6601.11	0.00
0.866769	710.82	6973.17	3.20	7036.54	7025.57	392.79
0.74928	717.98	7043.37	6.40	4960.77	4929.85	552.97
0.642565	729.90	7160.33	10.60	3863.57	3797.64	710.71
0.545337	746.49	7323.10	15.00	3107.70	3001.81	804.33
0	804.86	7895.64	15.00	2551.41	2464.47	660.35

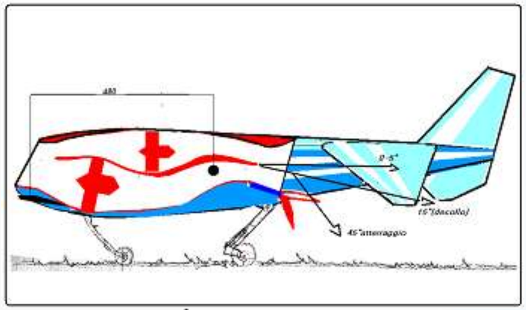
Dornier Do 28 D2 can take off from the garden behind my house...

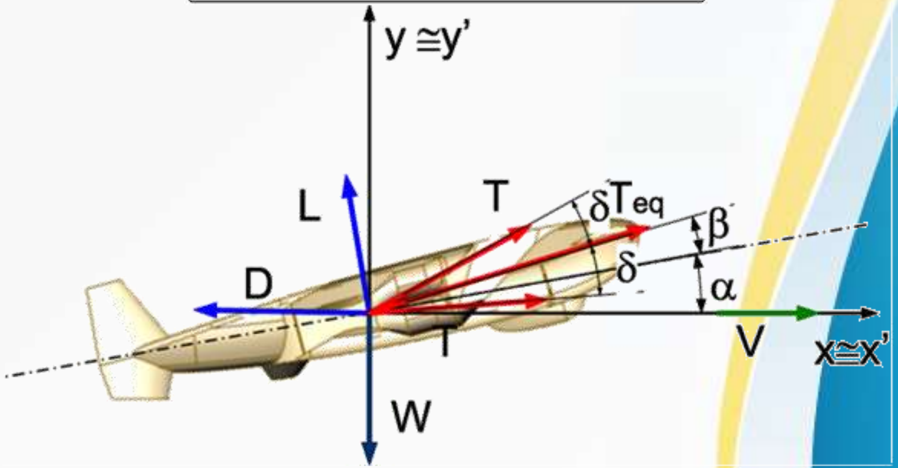
ACHEON allows reducing of more than 50% the needs in terms of landing an takeoff space:
from 170 m to less than 100.
Having some weight and payload
With RR series 250 turbofan cogeneration

…and let’s do it strange…









whow… it can work!

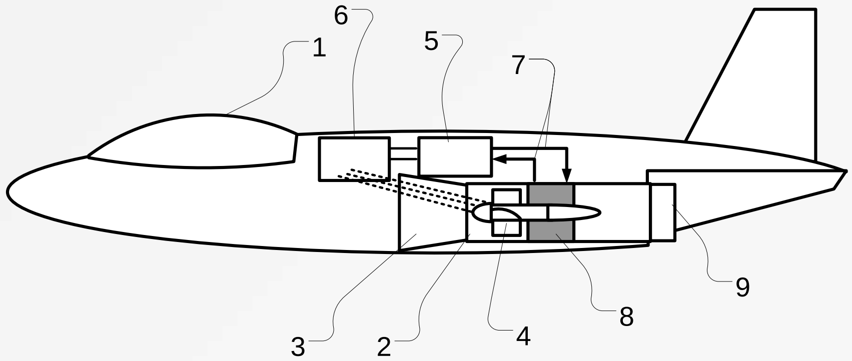
Component	Unitary mass	Number	Total mass
	G	-	G
Propellers	37	4	148
Motors	72	3	216
Speed control	26	4	104
Servo	85	4	340
Receiver	50	1	50
Battery	786.2	2	1572.4
Cabling and accessories	200	1	200
		Total mass	2630.4

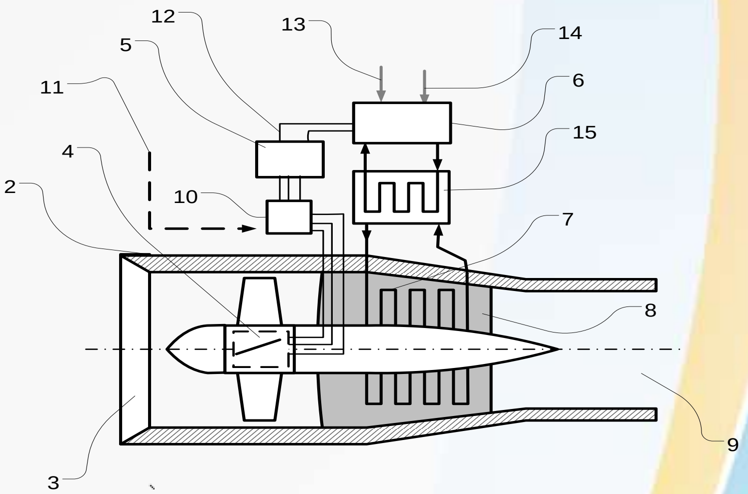


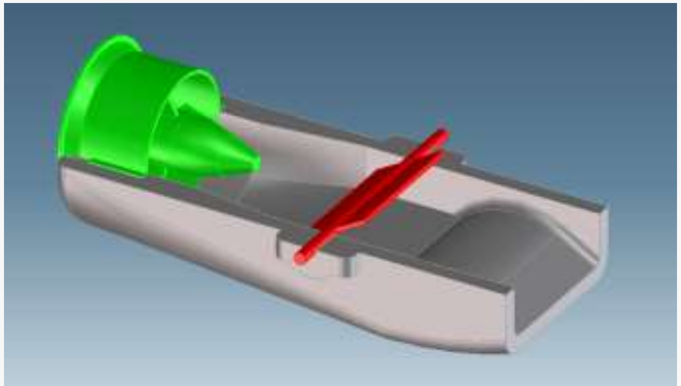
- Assuming an angle of attack of 7.5°
- Take off
  - angle of the fuselage and thrust 7.5° ,
  - max thrust takeoff,
  - Vstall about 9 m/s
  - Vtakeoff = 10.65,
  - takeoff length about 12 m,
  - acceleration of 3 m/s.
- Climbing
  - angle of 20° about
  - speed about 14 m/s
  - angle of attack 7.5,
  - Thrust is oriented upward with an angle of 15°
- Cruise
  - min speed about 10-12 m/s
  - cruise speed of 25 m/s
- Landing
  - landing lenght less than 12 m.

Less than 4 kg → **5 to 45 m/s**
About 4.000 €

…and how can we improve it?







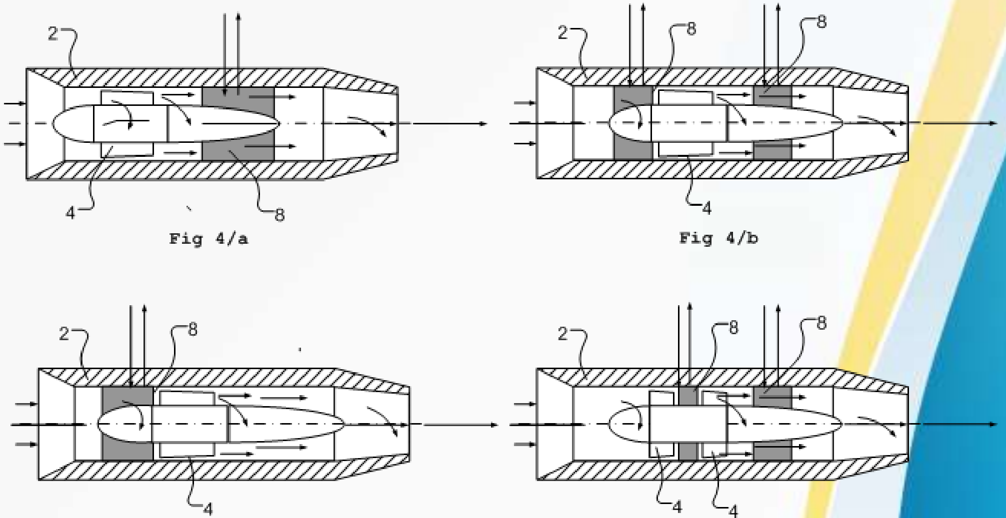


Fig 4/a

Fig 4/b

Fig 4/c

Fig 4/d

ACHEON balance...

- **600.000 Euro demonstrated that, even still embrional ACHEON works!**
- **We have demonstrated that ACHEON could fly...**
  ...actually on subsonic airplanes
- **it can be helped by thermal effects which needs further studies**
- **A large number of high quality papers produced**
- **Theoretical results reaches fully achieved TRL 2...**
  ... even if they need further studies and further experimental validations to be exaustive
- **... 2 patents... 1 connected patent.**
- **... UOL, UBI, and VUB experimental results have started the road through TRL 3...**
- **We have encuraged new research direction on Coanda effect**
- **We have met other research groups working on Coanda Effect...**
  ... they have also validated some results free of charge because of their scientific importance!
- **ACHEON according to UNIMORE has been a success!**
- **What do you think about continuing it????**

... and for tomorrow...
I think that ACHEON could work!

Thanks!

acheon

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